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AIR WAR COLLEGE

RESEARCH REPORT

THE GLOBAL POSITIONING SYSTEM

LT COL MARK J. FISCHER

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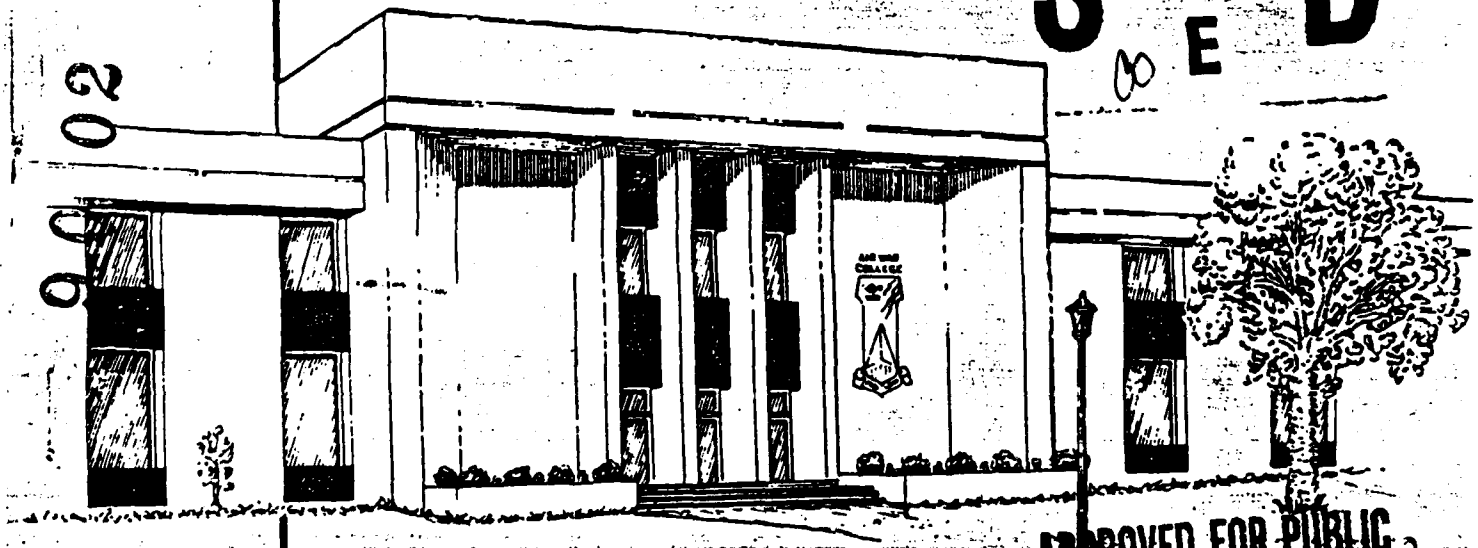

AIR UNIVERSITY
UNITED STATES AIR FORCE
MAXWELL AIR FORCE BASE, ALABAMA

AIR WAR COLLEGE
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THE GLOBAL POSITIONING SYSTEM

by

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A DEFENSE ANALYTICAL STUDY SUBMITTED TO THE FACULTY

IN

FULFILLMENT OF THE CURRICULUM

REQUIREMENT

Advisor: Colonel John M. Vickery

MAXWELL AIR FORCE BASE, ALABAMA

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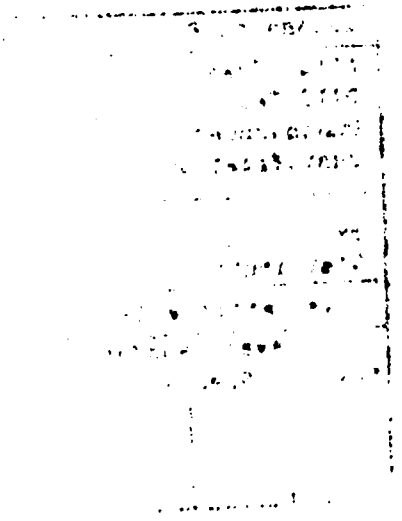

EXECUTIVE SUMMARY

TITLE: The Global Positioning System

AUTHOR: Mark J. Fischer, Lieutenant Colonel, USAF

A description of the Global Positioning System (GPS) and current program status are provided. The importance of timing and position data are highlighted, using several historical examples. Potential uses for GPS by all the military services are explored. The author examines the role of the current GPS program office. The major drawback to the program, in the author's view, is that GPS requirements are not addressed from a joint Department of Defense perspective. A solution to this deficiency is suggested.

BIOGRAPHICAL SKETCH

Lieutenant Colonel Mark J. Fischer is a 1972 graduate of the United States Military Academy. Upon graduation, he was commissioned a second lieutenant in the United States Air Force. His duty assignments include tours in California, Hawaii, Korea and Thailand. He attended both Squadron Officers School and Air Command and Staff College at Maxwell Air Force Base, Alabama. He received a Master of Arts in Business Administration from Central Michigan University in 1980. Colonel Fischer is a 1989 graduate of the Air War College, class of 1989.

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CHAPTER I

INTRODUCTION

The purpose of this study is to assess the impact the NAVSTAR Global Positioning System (NAVSTAR GPS or GPS) will have on future weapons employment. The study will: examine why we need a high precision positioning system; provide a brief explanation of GPS; explain how GPS will impact future warfighting capabilities; and lastly, give recommendations on how the initial acquisitions of GPS receivers should be fielded.

Warfighting tools throughout history have tended to keep pace with technology. A recent example of this was during our own Civil War. Robert C. Ehrhart in his article on the Civil War states:

> The American Civil War was the first major conflict to demonstrate the impact of the technological developments of the Industrial Revolution. Technology affected virtually every aspect of the war...[1]

I believe GPS will also significantly impact future warfighting capabilities and add beneficial dimensions only dreamed of years ago.

The military forces of the world today possess a myriad of highly technological equipment which provides diverse and expanded capabilities not attainable until this decade. Two examples of this "new technology" are the

stealth bomber and the Strategic Defense Initiative (SDI) or Star War's program. As a result of these kinds of evolving technological developments, the ability to accurately locate targets, rendezvous with friendly forces at a precise location and time, and to instantaneously determine one's own location have become essential in today's military operations.

CHAPTER II

THE CURRENT PROGRAM

The GPS is a $4 billion-plus program which will provide military users with a variety of potential applications.[2] These applications range from improvements in enroute navigation and position location finding to conducting anti-submarine warfare and to missile guidance systems. Later, this paper will address many of these applications in more detail. In addition to providing data 20 to 100 times more accurately than any other system yet developed, economic studies show millions of dollars can be saved by reducing the number of less accurate systems now in use.[3] One fact is uncontested and that is GPS will provide significant new capabilities and enhance the way we plan and execute our war and contingency plans.

The GPS is comprised of three segments: the Space Segment, the Control Segment and the User Segment. These are discussed below.

THE SPACE SEGMENT

The Space Segment will consist of 21 primary and three spare satellites that will orbit the earth. Each will be placed at an altitude of 10,898 nautical miles above the earth's surface with an orbital plane of 15 degrees to the equator.[4] The satellites will transmit continuously in the

1-2 GHz range. One set of transmissions (C/A Code or Clear Acquisition) will provide both civil and military users with precise positioning information. The second transmission, reserved for the U.S. military and allied/friendly users, employs the P Code for precision or pseudorandom data. These latter signals are encrypted, anti-jam protected and provide more precise positioning data. Some examples of these GPS capabilities are real time computations which can provide position, velocity, time, altitude, time and distance to waypoint, ground-speed, true magnetic heading and magnetic variation to our forces equipped with GPS receivers.[5]

Unfortunately and tragically, the 1986 loss of the Challenger space shuttle delayed the GPS program until launches could be resumed in late December 1988. Future launches will be a combination of the space shuttle and expendable launch vehicles. If all goes according to plan, total three-dimensional availability will be achieved in 1991 with the placement of 21 primary GPS receivers in orbit.[6]

THE CONTROL SEGMENT

The Control Segment is a land based system that will control system timing and satellite characteristics. There will be five unmanned ground stations located around the world to receive satellite data. These stations will be

located at Diego Garcia, Kwajalein Atoll, Hawaii, Ascension Island and Colorado Springs.[7] High precision receivers, atomic clocks and an IBM Series/1 computer at each station will format incoming information for system compatibility and then forward it on to the Master Control Station.[8]

In addition to the five unmanned ground stations, three unmanned ground antennas will be situated at key locations. These antennas will transmit command data to the orbiting satellites and relay satellite system data to the Master Control Station. These unmanned antennas will be located at Diego Garcia, Kwajalein Atoll and Ascension Island.[9]

Colorado Springs will be the site of the Master Control Station. This station will receive information from the ground monitor stations and antenna sites to ensure the overall control of the system. The master control station will perform such functions as calculating proper satellite positions and synchronizing the space vehicle and system clocks. It will track, monitor, reposition satellites and update them with highly accurate timing and location data. Commands generated by operations personnel can be sent to each satellite via the remote controlled transmitting ground antenna.[10] In short, the Master Control Station will check overall system accuracy and provide corrections when necessary.

The heart of the Master Control Station will be two IBM 3000 series data processing systems with ten interactive color consoles and communications facilities.[11] This facility will be manned with U.S. Air Force personnel.

THE USER SEGMENT

The final segment is the User Segment. As the name implies, this is the equipment that will be procured by the various users to obtain GPS data. Navigation radio receivers, which comprise the user segment, will passively track the satellites. As stated earlier, a variety of information such as time, location, speed, distance to waypoint, etc. will become available to the user.

The GPS receiver calculates the distance to each of three satellites by measuring the transit time of the received signal and multiplying that time by the speed of light to compute pseudorange.[12] Of course, there will be a multitude of mathematical calculations, system accuracy checks and other highly sophisticated actions. However, for the purpose of this paper, the details of these transactions are unimportant. The key concept to remember is that the User Segment Equipment will use positioning data received simultaneously from at least three satellites. This in turn will provide the user with precise positioning data.

It is estimated that GPS receivers will be integrated into more than 200 types of military host vehicles for the three military services.[13] Some of these include manpacks, land vehicles, ships, aircraft and submarines. The GPS user equipment currently consists of: a one-channel manpack/vehicle configuration for backpack, land vehicle and small watercraft applications; a two-channel configuration for helicopters and fixed wing aircraft where moderate acceleration is expected; a five-channel configuration for Air Force and Navy high performance aircraft; and a five-channel configuration for Navy ships and submarines where rapid signal acquisition is required.[14]

All of the receivers provide position, velocity and timing data. Recent tests of the system show that GPS receivers provide better than 16 meter position accuracy.[15] Accuracy testing has been performed on a number of platforms by all three services. The U.S. Army tested GPS manpack equipment as well as a two-channel receiver in an UH-60 helicopter. The U.S. Air Force tested a five-channel receiver in both an F-16 and B-52 aircraft. The U.S. Navy tested GPS equipment in the A-6 aircraft and SSN-701 attack

submarine.[16] These tests demonstrate that GPS is living up to its advance billing. Specifically, they demonstrate that the GPS:

- meets aircraft nonprecision approach requirements
- provides the ability to perform fast, accurate in air inertial navigation system alignment
- provides the capability to counteract hostile jamming
- provides the capability to enhance combat aircraft mission success, especially weapons delivery
- allows precise maneuvering to a given waypoint
- provides 12 meter accuracy (spherical error probable) for two-channel systems
- provides five-channel three dimensional accuracies of up to 13 meters (spherical error probable)[17]

CHAPTER III

IMPACT ON FUTURE WARFIGHTING

Successful wars are normally won by the execution of carefully constructed plans. Among the many factors war planners have long considered are timing, coordination and the precise knowledge of terrain. The importance of these elements cannot be overstated. In fact, they are among Clausewitz's universally recognized Principles of War. The Global Positioning System will enable war planners to exploit these principles to their advantage.

One does not have to turn back the pages of history too far to see how timing and the ability to determine one's precise location are essential. For instance, the invasion at Normandy was planned with considerable emphasis placed on timing and invading at precise landing locations. However, due to imprecise position locating and some inaccurate navigation instruments, elements of the invasion forces landed at the wrong locations. Fortunately, the overall outcome was not affected. However, such an error could very well have changed the course of history.

A more recent example occurred during the 1983 invasion of Grenada. As with any complex military operation, timing, coordination and precise location data were essential. While the operation was a success, it highlighted some existing

deficiencies in our ability to determine precise location data. In testimony before the Full House Committee Hearing on the Lessons Learned as a Result of U.S. Military Operations in Grenada, Admiral Wesley McDonald, the then Commander-In-Chief, U.S. Atlantic Command, brought this deficiency to light. In his testimony he stated:

> The Army, particularly the troops on the ground, were operating initially from roadmaps or other types of maps which made it very difficult for them to determine their grid coordinates. That is one of the lessons learned.[18]

Operation Urgent Fury, as the invasion was called, was a success-- U.S. citizens were protected and evacuated; opposing forces were neutralized; the situation was stabilized with no additional Cuban intervention; and a lawful, democratic government restored.[19]

Of course, there will always be those, (such as this author) who will look at both of these operations-- the Normandy and Grenada invasions-- and speculate what "could have been" had Lady Luck not intervened. Hopefully, GPS will take the place of Lady Luck and enable the war planners of tomorrow to eliminate a known deficiency (our inability to precisely pinpoint one's position), one which has plagued warfighters for as long as wars have been fought. It is clear, position, navigation and timing are essential requirements for today's warfighters. Without these

capabilities, the best and most modern training can be rendered useless.[20]

How will GPS enhance our war fighting capabilities? Let's look at some possible scenarios. One example might be GPS capabilities to augment the new B-2 advanced technology (stealth technology) and other "exotics".

Imagine a B-2 bomber cruising over enemy territory in wartime waiting to be notified of the location of mobile targets such as rail- and truck-based ballistic missiles. This initial information would be provided by U.S. reconnaissance satellites.[21]

Once the bomber received the target information, the on board GPS receiver would give an immediate course and distance to the target. Directions to the target would then be fed into the guidance system of a standoff missile carried on the B-2 bomber. The mobile target would then be precisely marked, the missile fired and the target destroyed within minutes rather than the hours currently required to conduct such an operation.[22]

Other scenarios that could easily be envisioned are the use of GPS receivers to provide precise guidance information to remotely piloted vehicles (RPVs), standoff missiles and unmanned reconnaissance aircraft. GPS would also be ideal for accurately marking the position of underwater shoals, buoys, mine fields and conducting blind bombing.[23]

Of course, the GPS will help the individual soldier accurately determine his position so that a rendezvous can be planned, close air support precisely targeted and artillery placed with remarkable speed and accuracy. Soldiers equipped with a GPS receiver will know their position with an accuracy of within 10 meters and be capable of navigating to their destination using programmed waypoints. As they move, the GPS receiver will provide direction, distance and timing data. In fact, timing data will be so accurate, it will be within 100 nanoseconds.[24]

All of this capability will not be at the expense of much additional weight or bulk. In fact, the current GPS manpack receiver weighs less than ten pounds and is less than 200 cubic inches, including the battery and antenna.[25] Future units may even be as light as five pounds and only 100 cubic inches.[26]

Hopefully, situations such as those that occurred at Normandy and Grenada, will be things of the past. With GPS, soldiers, sailors and airmen will know their precise location at any given time and at any place on the surface of the earth.

Military applications for GPS are unlimited. They are constrained only by the limits of one's imagination. Special operations, search and rescue, aerial refueling, aerial bombardment, intelligence, electronic warfare, artillery

placement, navigation, reconnaissance, etc., are but a few applications. It is not inconceivable that GPS receivers will become standard equipment in all aircraft, naval surface vessels, submarines, land vehicles and manpacks-- as well as manned and unmanned space craft.

CHAPTER IV

PROCUREMENT STRATEGY

The Global Positioning System will affect all Department of Defense (DOD) agencies as well as many civilian and federal agencies. Because of its applicability to all DOD agencies, a joint GPS program office was established. It is the stated responsibility of that office to collect and consolidate service requirements and then develop a joint procurement program.

The GPS joint program office is manned with representatives from each of the military services. Working closely together, they have successfully consolidated all of the military services' requirements and developed a joint statement of need. Based on this consolidated statement of need, several major companies such as Rockwell Collins, Magnavox, Teledyne and others have submitted proposals to develop the required equipment. As stated earlier in this paper, initial tests have been conducted and have met with much success. As a result, low rate initial production has been started. The next step is for the services to make a final decision on their GPS requirements.

This is not to suggest that the test and development phase is complete. A recent briefing on GPS status indicated some problems with some of the GPS units still exist.[27]

These problems center primarily around size and weight constraints. However, they are being aggressively handled and these limitations should be successfully resolved.

The issue that needs to be further addressed is how future GPS acquisitions will be deployed. Notwithstanding the fact we have a joint development office, GPS procurements are being separately handled by the individual services. There does not appear to be any integrated scheme for GPS procurement. As a result, each service will soon prioritize their GPS user requirements based on their individual needs. I submit that the GPS DOD procurement sequencing priorities should be developed by a joint GPS requirements board that would be tasked with putting together a consolidated procurement strategy for all the military services.

While service needs must be addressed, I believe it is more prudent to first field GPS units to meet the collective and more immediate needs from a joint rather than an individual service perspective. Since we will go to war as a joint entity, it makes good sense that we procure our equipment as a joint entity. It will do little good to deploy if the individual services do not have the same GPS capabilities. In such a scenario, we would be left to accept the lowest common denominator for operational effectiveness.

The result: many GPS benefits described earlier in this paper could go unrealized.

I recommend that an integrated procurement strategy be built based upon where the need is envisioned to be the greatest-- and from a joint perspective, thus setting aside any service prejudices and parochialism. This may mean that one service's requirements may be implemented before those of another service-- but that's how it will have to be, and it shouldn't make any difference if we- Army, Navy/Marine Corp, Air Force, start thinking "purple".

A good starting point would be with the spectrum of conflict. The following figure depicts Professor Sam Sarkesian's Conflict Spectrum.[28] The Sarkesian Model, in one fashion or the other, has been generally accepted as a model which reflects the relative likelihood for a particular level of warfare being reached. It ranges from the lowest level of conflict, non-combatant force, to the ultimate, or full scale nuclear war.

From recent events, such as current developments being made in arms control and Mr. Gorbarchev's several announcements that the Soviet Union is now interested in keeping a more peaceful world

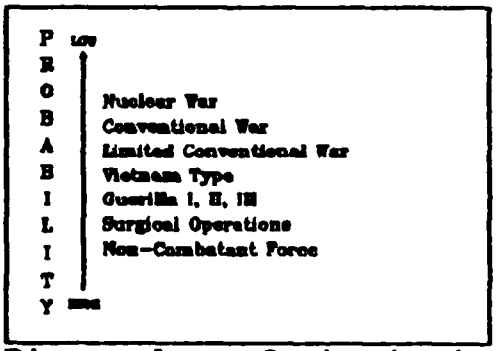

Figure 1. Sarkesian's Spectrum of Conflict

environment, the probability for a full scale nuclear war is low. This is clearly depicted in Figure 1. However, the likelihood of low intensity conflict is at the opposite end of the spectrum, with a much higher probability of being realized. The probability that low intensity conflict will seriously affect U.S. interests is more and more imminent with each passing day.[29] I believe, recent events have shown this to be the case. A series of events from the bombing of the U.S. Marine barracks in Beirut and the Grenada invasion to the proliferation of hostage taking, hijacking of aircraft, and other terrorist activities clearly highlight this point.

If one accepts this premise, then one can reasonably conclude that the United States military must continue to place a greater emphasis on meeting-- and containing the threats imposed by low intensity types of conflict. Therefore, a joint GPS requirements board should first look at low intensity conflict needs. These needs could run the gamut from special operations such as hostage rescue all the way to a sophisticated raid such as that conducted over Libya in 1985. Many defense experts,

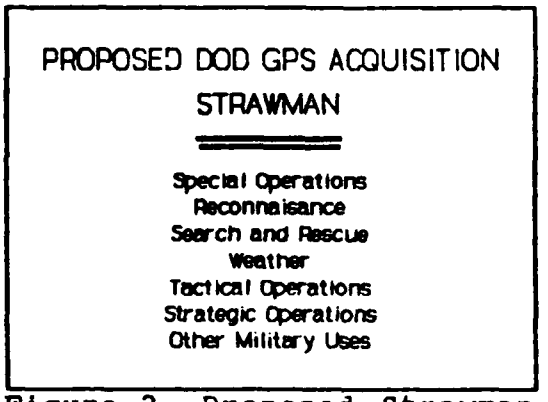

Figure 2. Proposed Strawman for DOD GPS Acquisitions.

both within and outside DOD, agree that the United States has under-emphasized force allocation, doctrine, training, and equipment for the one level of conflict most likely to arise.[30] Additional GPS requirements, could follow a similar pattern, using Sarkesian's or another similar model. Figure 2 is a strawman presentation for a DOD GPS hypothetical hierarchy of procurement priority and mission requirements based upon Sarkesian's Conflict Spectrum. It is not meant to be all inclusive but rather to provide a point of departure for homogeneously addressing GPS joint requirements.

The GPS requirements board would be responsible for consolidating and prioritizing service requirements in concert with an approved DOD joint acquisition plan. Again, the architecture should focus on where the need is the greatest and the likelihood for force deployment/employment the greatest.

CHAPTER V

CONCLUSION

The Global Positioning System will have a significant impact on how we conduct future operations and deploy weapons systems. Throughout the recorded history of warfighting, man has been highly dependent upon timing and location. Clausewitz, in his Principles of War, highlights the importance of these two elements. With GPS operational, military users will have precise location and highly accurate timing data available virtually instantaneously. Clearly, our warfighting capabilities will be greatly enhanced and future improvements limited only by man's imagination.

The Joint GPS Program Office has done a superb job in consolidating each service's operational requirements. As a result of this, initial tests have been extremely promising and initial low rate production has been started. The issue that must now be addressed is how we, DOD, go about equipping the services. At the present time, each service will independently establish its own priorities. I do not believe this is the way to go.

I believe a joint GPS requirements board must be established to ensure joint DOD priorities are met first, regardless of service desires and parochialism. A starting

point for developing a DOD strategy for prioritorizing service needs, could be the Sarkesian Conflict Model. It depicts the ranges of conflict (noncombatant to nuclear) and their relative likelihood for being initiated. This model, in one form or another, has been accepted by leading defense analysts and historians.

Regardless of whether one completely accepts the Sarkesian Model or another similar one, the end result would be the same-- DOD would procure GPS user equipment based upon an integrated plan placing the highest priorities on those areas where the greatest likelihood for actual deployment and/or employment is the greatest. In a time when DOD dollars are shrinking, we must make every one count. Services are going to have to set aside service prejudices and parochialism and begin to think "purple". A Global Positioning System prioritization equipage board offers an excellent opportunity to continue this joint program, demonstrating the spirit and intent of the Goldwater-Nichols DOD Reorganization Act of 1986.

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